I.8. Assimilation of SSM/I surface wind speed

The assimilation of surface wind speed from the Special Sensor Microwave/Imager (SSM/I) was designated as a priority data set in ATBD-96. The DAO has conducted a number of impact tests involving the use of SSM/I surface wind speed data in GEOS-3 and GEOS-2. A specific example of the positive impact of SSM/I wind speed data in a 2x2.5 degree version of the GEOS-2 DAS is shown in the lower panel of figure 12 in Atlas et al. (1999). In that example, the SSM/I data improved the anomaly correlation forecast skill (for eight cases) in the Southern Hemisphere by as much as 12 hours, three days into the forecast, over the control case that did not use these data. The forecast impact of these data on the GEOS system in the Northern Hemisphere is neglible. These results are broadly representative of the forecast impacts found in version 3 of the GEOS DAS. More generally, however, Chin et al. (1998) showed that the SSM/I wind products significantly improved the calculation of fluxes of trace species across the ocean surface. Furthermore, the SSM/I are important for providing a background representation of the state of the sea surface to benefit the impact of other wind instruments when they are available. (i.e. scatterometers, see C.5 New Data / Scatt.)

I.9. Assimilation of SSM/I total precipitable water

Assimilation of SSM/I-derived total precipitable water (TPW) estimates has proven to provide an effective means to reduce moisture biases and improve aspects of the hydrological parameters in GEOS assimilation products (Ledvina and Pfaendtner 1995). Improving the moisture assimilation products is important for applications by many of EOS Instrument Teams. At the present time the SSM/I TPW is assimilated in the GEOS system by adding a TPW-induced moisture analysis increment to those derived from a univariate moisture analysis based on conventional data in the moisture tendency equation. The work of Hou et al. (2000a, 2000b) showed that assimilating SSM/I TPW in the tropics significantly improves in the outgoing longwave radiation (OLR), which is a special concern of the CERES (see Section II.1).

The GEOS-2 moisture analysis is significantly biased relative to that produced by the operational ECMWF system, which assimilates TOVS radiance data. Moreover, the spatial patterns of the discrepancy between the two analyses are, to a high degree, correlated with the error structure in the TPW from the GEOS-2 assimilation with respect to the SSM/I TPW estimates. The GEOS-Terra system currently assimilates the real-time NESDIS TPW retrievals from three SSM/I instruments. Figure 11 compares the TPW products from the GEOS-2, the GOES-Terra, and the operational ECMWF system against the Wentz TPW estimate for January 1998. The GEOS-Terra TPW shows the smallest bias and error standard deviation. Figure 12 shows that TPW assimilation also brings the upper tropospheric moisture analysis in the GEOS-Terra closer to the ECMWF analysis for January 1998. These improvements are responsible for the improved clear-sky OLR over oceans discussed in section II.1.

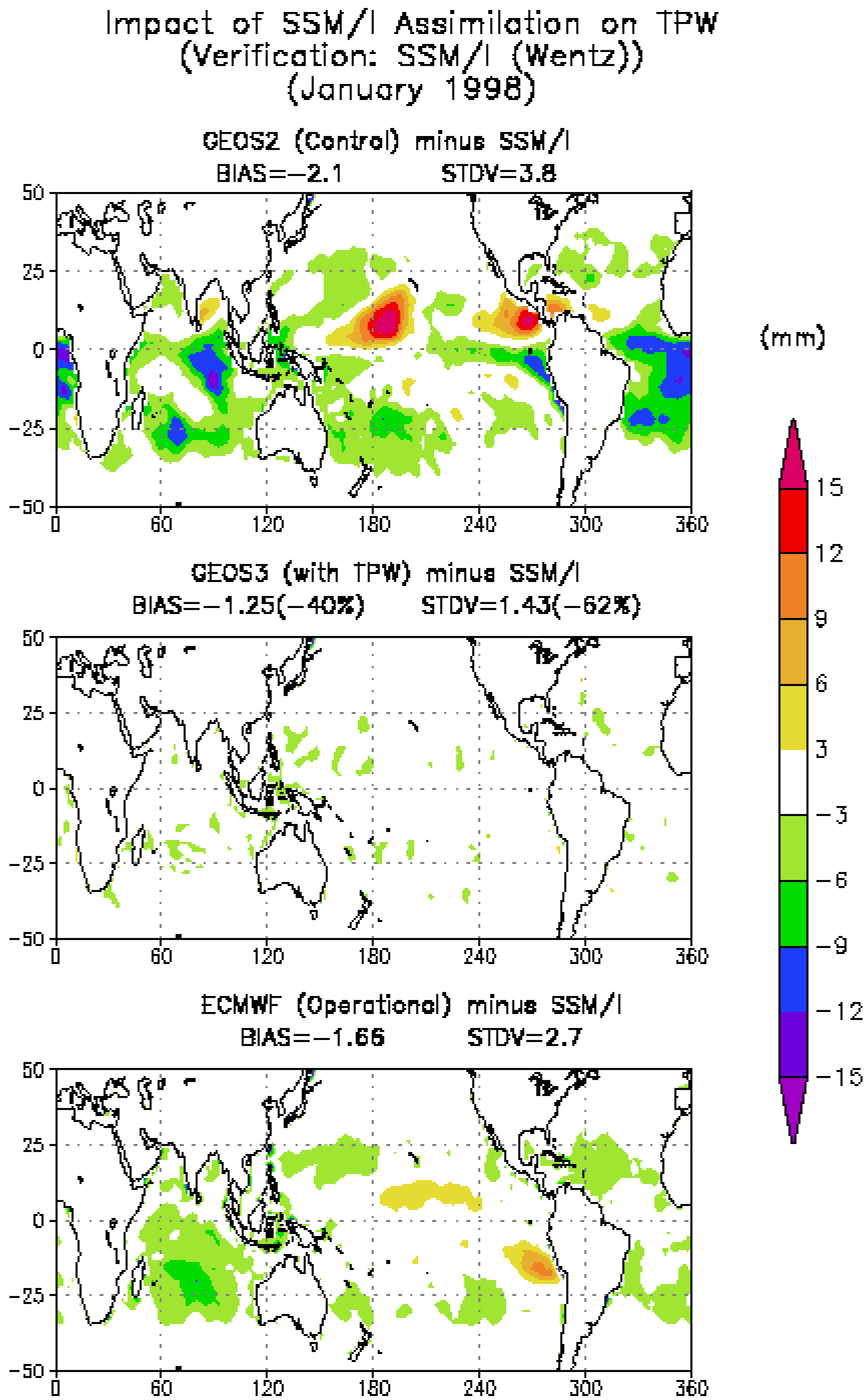

Figure 11: Comparison of total precipitable water (TPW) from GEOS-2, GEOS-3 (Terra), and the operational ECMWF analysis for January 1998.

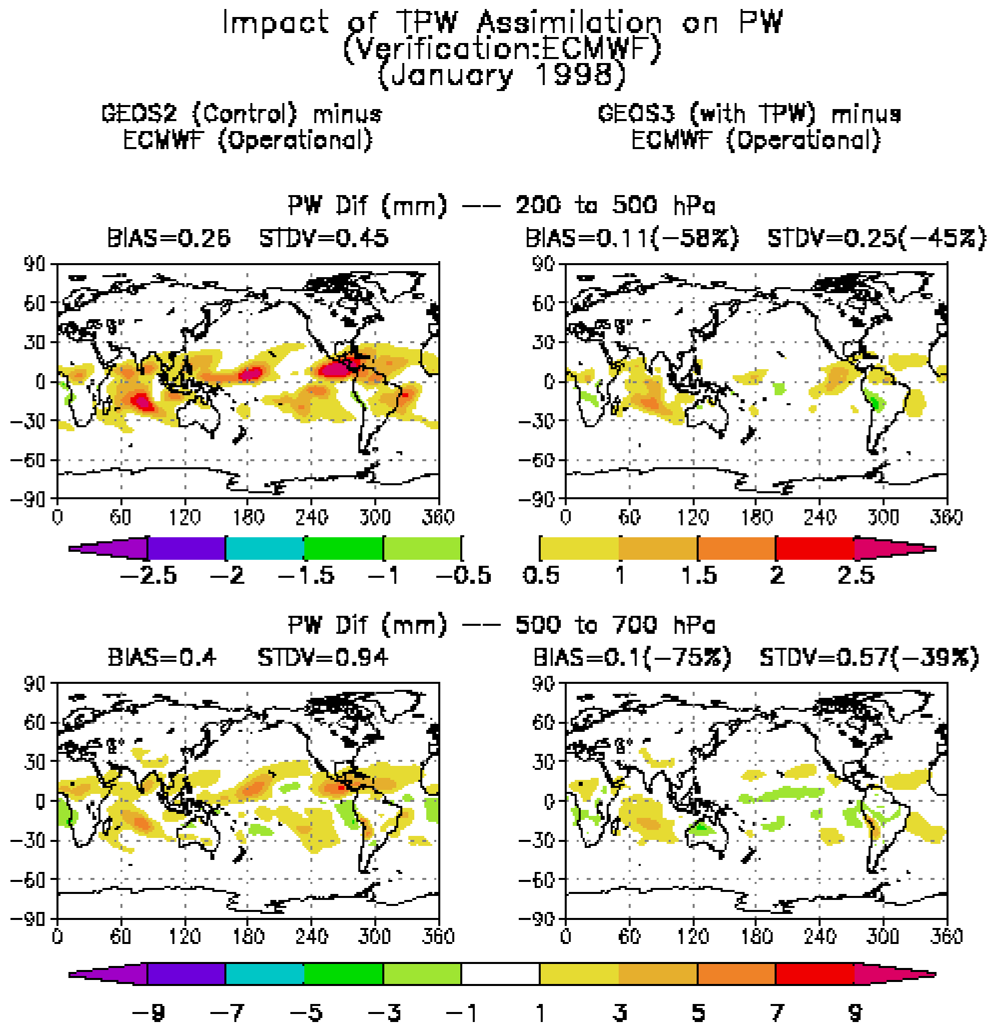

Figure 12: Total pricipitable water (TPW) assimilation also improved the upper tropospheric precititable water (PW) estimates as compared with the operational ECMWF analysis which the CERES/TRMM science team determined to be more consistent with radiative calculations.

II. Applications and customer feedback.

This section summarizes the assessment of the quality of GEOS-3 DAS products in representative applications. Much of the section focuses on interactions with the CERES/TRMM science team. The CERES/TRMM team, in 1997 and 1998, identified a number of particular shortcomings of the GEOS/TRMM product and represents the ability of the DAO to respond to representative science problems of the NASA instrument community.

To help formalize the interactions with the instrument teams, a DAO- Instrument Team Mini-Workshop was held on November 30 and December 1, 1998 at Goddard to establish a working partnership between DAO scientists and instrument team investigators. The main purposes of the Mini-Workshop were to understand the usage of DAO products by the individual instrument teams and identify targets for DAO product improvements. The instrument team representatives discussed their experience in using DAO products in terms of limitations of the current products and future needs. DAO presentations highlighted recent improvements and the ability and willingness to customize products to customer requirements and future capabilities. At this workshop, the DAO designated staff members to be the DAO Point-of-Contact (POC) for each of the instrument teams, who will attend the instrument teams science meetings regularly and keep the instrument teams apprised of the latest developments of the GEOS DAS. A web page was also set up to update the instrument team requests/concerns and DAO responses. A detailed report on the DAO-Instrument Team Mini-Workshop is available on request.

II.1.1. Improving GEOS data for CERES SARB applications

CERES was one of the first instrument teams using DAO's assimilation data products. They require the temperature and moisture profiles, ground temperature, and surface pressure fields to compute the clear sky outgoing longwave radiation (CLR) and to retrieve cloud properties. In a CERES Science Team meeting held in April 1998, the Surface and Atmospheric Radiation Budget (SARB) Group reported that the computed CLR produced by the GEOS- 2 DAS was too low in comparison with the CERES CLR observations and the diurnal cycle of the ground temperature too flat compared with the ISCCP data (Clouds). Further they found better agreement with their expected values when using similar products from ECMWF. They also suggested that the reason for the low CLR was a moist bias in the DAO moisture analysis between 200 to 500 hPa.

DAO scientists took immediate action to address the concerns of the CERES Instrument Team. Off-line radiation computations using the same data showed that the reason for the low computed CLR was due to a moist humidity bias between 200 and 500 hPa over the oceans and excessively low ground temperatures over land. These results were presented at the DAO-Instrument Team Mini-Workshop held at GSFC in November 30, 1998.

The implementation of the interactive land surface scheme (Section I.1), the moist turbulence scheme (Section I.2), and TPW assimilation (Section I.9) in the GEOS-Terra has improved the CLR field as validated against the CERES/TRMM ES-4 ERBE-like product. Figure 13 compares off-line calculations of the CLR over the oceans for the GEOS-2, GEOS-Terra, and the operational ECMWF system for January 1998. The global-mean bias and error standard deviation in the GEOS-Terra CLR are comparable in quality to the ECMWF product. Over the oceans, these improvements reflect primarily the benefits of TPW assimilation. Figure 14 shows a similar improvement in GEOS-Terra CLR relative to the GEOS-2 system for July 1998.

II.1.2 Improving GEOS data for CERES cloud property retrievals

The CERES-Cloud group uses GEOS-DAS data to retrieve cloud properties, such as cloud top and based altitudes, cloud amount, particle sizes, etc. They found that using the GEOS-2 data has enabled them to retrieve more realistic cloud amount than using the ECMWF data when compared with observations. But they could not retrieve realistic cloud top and base altitude over inversion regions when the used the GEOS-2 data. Tests are underway to see whether the GEOS-Terra products represent an improvement over the GEOS-2 products.

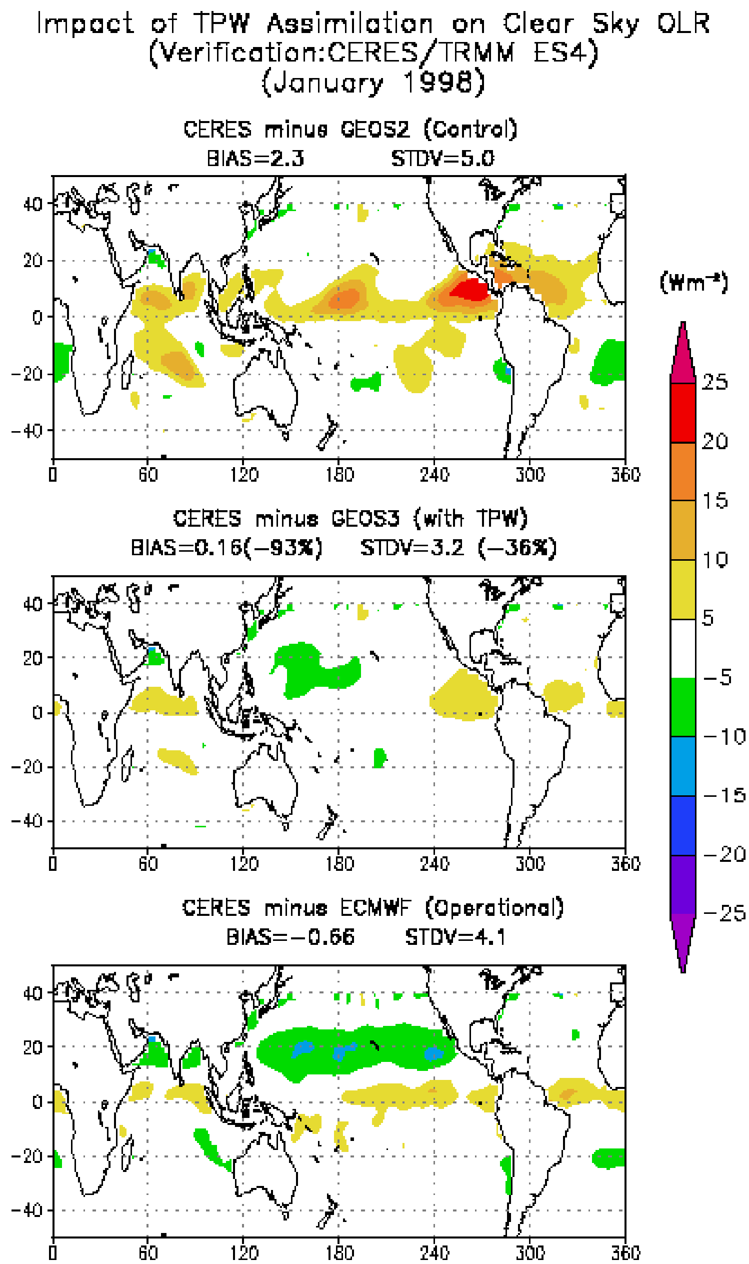

Figure 13. Monthly-mean spatial errors in clear-sky OLR over the oceans in GEOS-2 (top), GEOS-Terra (middle), and operation ECMWF analysis (bottom) with respect to the CERES-TRMM ES-4 ERBE-like estimate for January 1998. The percentage bias and error standard deviation reductions in GEOS-3 relative to GEOS-2 are shown in parentheses. Results are based on offline radiative transfer calculations using 36-level temperature and moisture analyses.

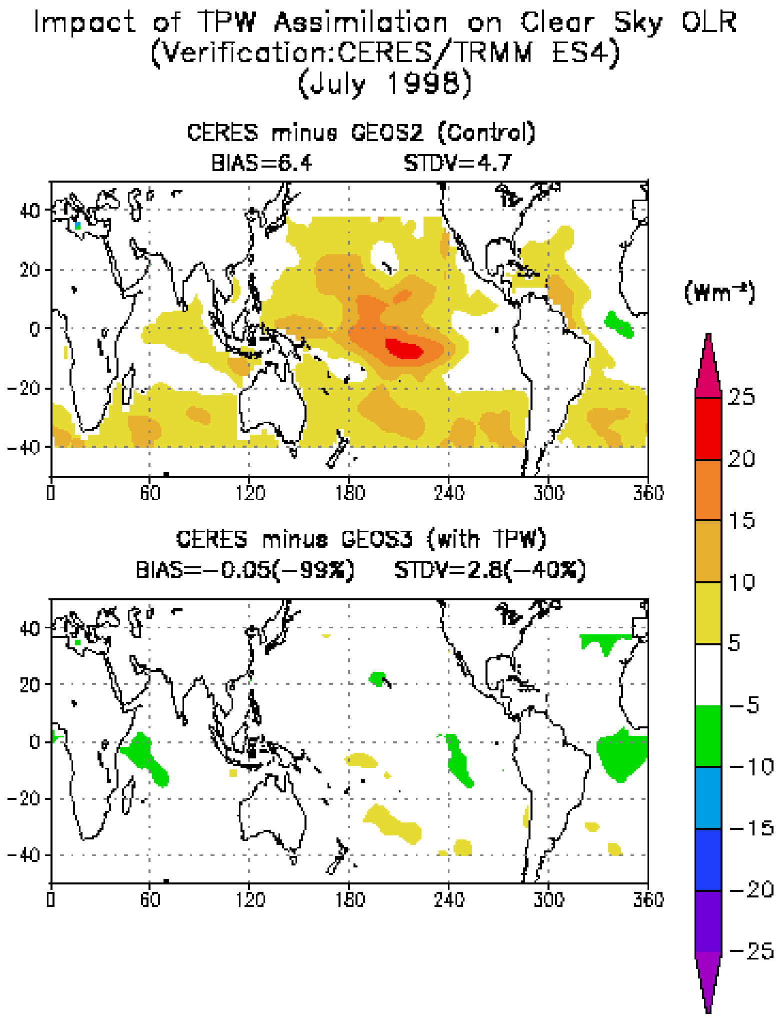

Figure 14. Monthly-mean spatial errors in clear-sky OLR over the oceans in GEOS-2 (top) and GEOS-Terra analyses (bottom) with respect to the CERES-TRMM ES-4 ERBE-like estimate for July 1998. (Note: The ECMWF results are not yet available for this period.)

II.2 NASA mission support

Over the years the DAO has supported many of the stratosphere and tropospheric aircraft missions focused at understanding atmospheric chemical processes. DAO analyses and forecasts are being used in the 'SAGE-3 Ozone Loss and Validation Experiment' (SOLVE), which is taking place in the Arctic in the winter 1999/2000. The mission is based in Kiruna, Sweden, with participation from the NASA DC-8 and ER-2 aircraft carrying a suite of 'in-situ' and 'remote sensing' instruments. Companion groups, sponsored by the European Union, will augment the NASA aircraft observations with the DLR-Falcon and several balloon-based instruments, some of which carry payloads from U. S. – based researchers. The essential science problem being addressed by SOLVE is the meteorology, physics and chemistry of ozone loss in the Arctic polar vortex in early, middle and late winter. The aircraft will be directed into regions of low temperature, where polar stratospheric clouds (PSCs) are likely to form.

The major use of DAO analyses and forecasts is to isolate regions that are cold enough for PSC formation (generally colder than about 195K at 50hPa, the precise details depending on the humidity and other trace gas concentrations). In addition, DAO analyses are being used to drive a chemistry-transport model, producing near-real-time simulations of trace species distributions. Over the three weeks of the January 2000 deployment there will be enough resources for about seven flights into the polar stratosphere, which must be planned in advance with regard to (a) the scientific questions to be considered and (b) the feasibility of flying to the cold regions; the latter issue is of paramount importance for the ER-2, which cannot fly in regions of extreme turbulence. Accurate forecasts are needed to design any of several predetermined 'flight plans' which include transects of the cold regions and attempts to fly along streamlines along the vortex edge, passing through air masses upstream and downstream of polar stratospheric clouds to measure changes in the chemical composition along trajectories. Because some advance planning is needed to determine when the appropriate meteorological conditions abound, the five-day forecasts are an invaluable product for scheduling flights. As the flight-day approaches, the shorter-term forecasts and analyses will be used to help fine-tune the flight plan and, in cases of extreme (and unexpected) development, to re-plan the flights. Examples of the products and their applications for current and past flights are found at

http://code916.gsfc.nasa.gov/SOLVE/

More general information about SOLVE is found at

http://cloud1.arc.nasa.gov/solve/solve.menu.html

Critical parameters for these missions are temperature, since the most useful flights will involve crossing cold regions, and winds, which are needed to plan the flights, taking issues such as flight duration/aircraft range and locations of likely extreme turbulence into account. These latter regions can be identified using mesoscale models of gravity wave propagation, for which the DAO analyses are used as the background state. These turbulence forecasts can be viewed at

http://uap-www.nrl.navy.mil/dynamics/html/mwfm_solve1.html

II.3 Synoptic evaluation and forecast applications

As discussed in ATBD-96 synoptic evaluation is an important part of the DAO validation plan. In addition to forecast skill, the structure of the different disturbances are assessed by their conformance with accepted conceptual models. For instance, the evolving thermal structure of an extratropical cyclone can follow either the Norwegian or the Shapiro-Keyser model. So far, there are not metrics to quantify the three-dimensional thermal structure, so it must be evaluated qualitatively. With regards to the kinematic structure, some constraints can be utilized in the synoptic evaluation. For example, the distribution of speed around a sub-stratospheric jet should satisfy non-negativeness (non-positiveness) of the absolute vorticity in the northern (southern) hemisphere.

Over the years the DAO has increased its use of weather forecasting for validation activities. Indeed, given the heritage of data assimilation in weather forecasting, knowledge of the forecast skill is expected by many DAO product users. Further, since NASA and DAO strategic goals now target to facilitate the use of NASA satellite data in weather forecasting applications, the DAO routinely uses forecasting to evaluate the potential impact of new data types. Another important forecast-related metric is the impact of introducing a new data type on the acceptance of standard high-quality data, e.g. radiosondes, during the assimilation cycle.

Previous reviews have pointed out that the GEOS-1 model did not provide forecasts of acceptable quality for a major assimilation center. In particular, the short-term forecast, less than 48 hours, was not up to the standards set by other organizations. This was particularly troublesome as it implied that the GEOS-1 system would reject potentially good data because of a poor short-term forecast. While the choice of validating analysis and filter application prior to performing standard forecast diagnostics exaggerated the inadequacies of the GEOS-1 model, the DAO accepted the fact that the forecast capabilities of the GEOS system required improvement.

The forecasting capability of the GEOS system has improved significantly (Figure 15). Compared with the first GEOS-2 forecasts presented at the 1997 review of ATBD-96, the decay of the anomaly correlation is less than half at 48 hours. Preliminary results from the one-degree model used in GEOS-3 are promising, but adequate statistics have yet to be developed.

As mentioned in Section I.3, increasing the horizontal model resolution from 2x2.5 in GEOS-2 to 1x1 in GOES-Terra GCM has a significant impact on the ability to produce realistic synoptic features. This improvement carries through to the analysis as shown in Figure 16, which shows a typical example of the synoptic behavior of the surface fields in the 1x1 analysis product. This assimilation uses the SSM/I wind speeds, but the NSCAT data are not assimilated. Using the retrieved surface wind vectors from the NSCAT Scatterometer as independent verification, the figure shows that the sea level pressure (contours) and winds (blue barbs) at 22 January 1997 at 00 GMT produced by the 1x1 GEOS Terra DAS are in excellent agreement with the NSCAT data (red barbs). Of particular note, the discontinuity in the frontal zone stretching east-west at about 41 degrees N to the east of the center of the low is well represented in the assimilation.

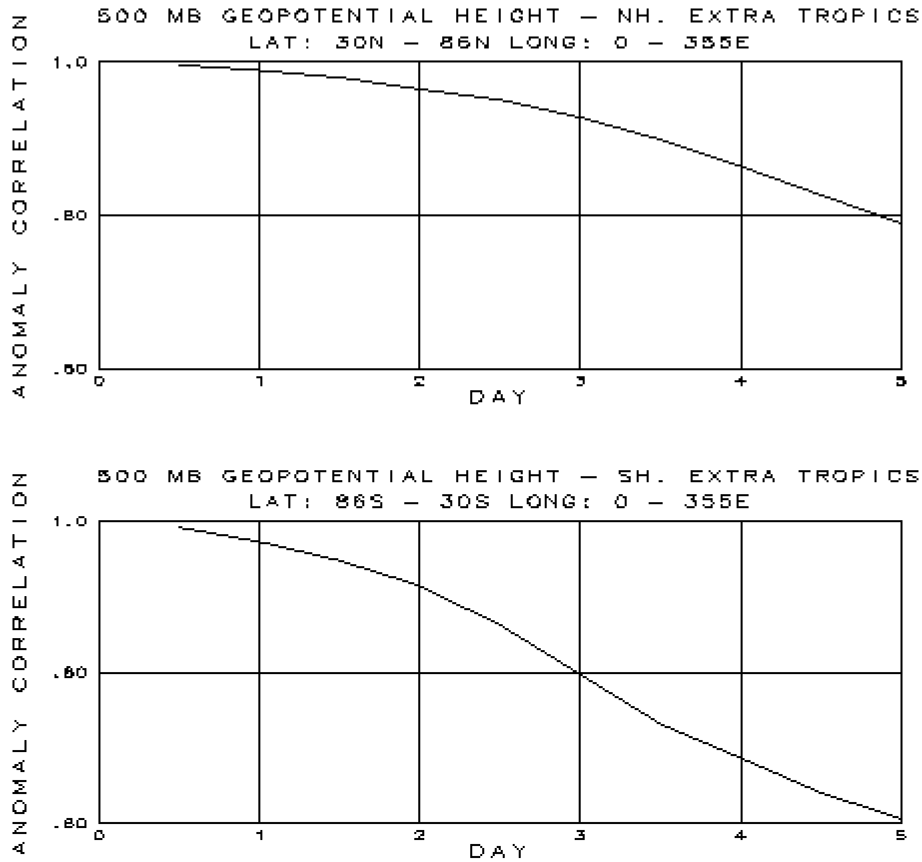

Figure 15: Anomaly correlation forecast skills for the Northern and Southern hemispheres using a 2x2.5 degree version of the GEOS-3 forecast model. Analyses from the corresponding GEOS DAS were used as the verification. In both figures, an ensemble of 11 5-day forecasts from July, August and September 1999 was used.

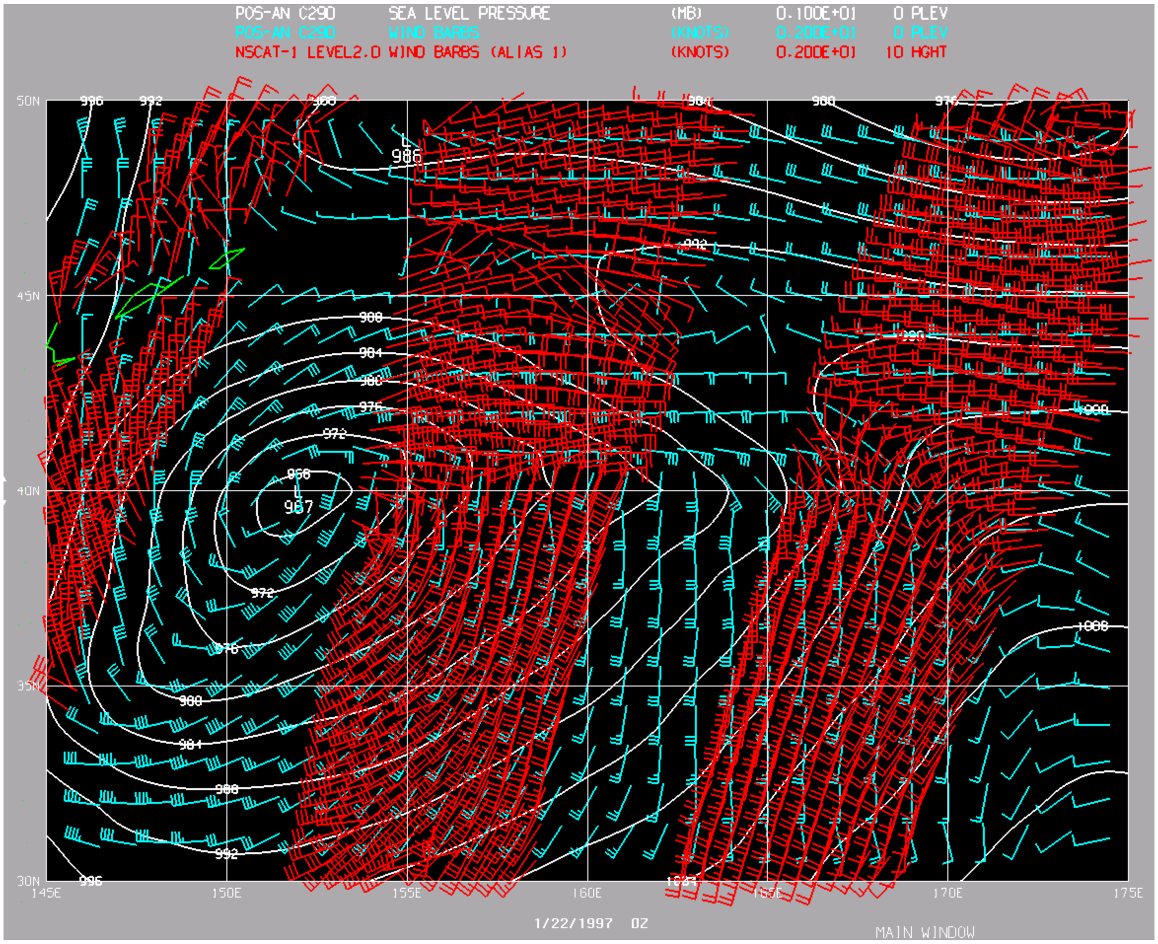

Figure 16. Comparison of GEOS-Terra surface wind analysis with independent NSCAT Scatterometer wind data collected within 20 minutes of the analysis time.

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